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DESIGN OF PRESSURE VESSEL FOR IMPROVEMENT OF A SYSTEM IN A PROCESS UNIT

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ABSTRACT

Vessels that carry, store, or get hold of fluids are known as pressure vessels. A pressure vessel is a containerwith a pressure differential between internal and outside. In the present paper, it has been discussed regarding the design of the pressure vessel according to the available code. New pressure vessels are being installed in a unit of petrochemical industry situated in Mangaluru, to fulfil the process requirement of the fluid which runs in the same unit. The design of pressure vessel is of most important in the industries, as failure of which will be hazardous and cause damage to the plant. This paper gives insight on how ASME section VIII division1 was used to carry outthe design of the particular pressure vessel.

KEYWORDS: Pressure Vessel & ASME Section VIII Division I

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Original Article

1. INTRODUCTION

Pressure vessels were utilized in a variety of industries; for instance, the energy generation firm for fossil and atomic power, the petrochemical firm for storing and process crude fossil oil in tank farms also as storing fuel provision stations, and also the industries of chemicals to call however a couple of. Their use has distended throughout the globe. Pressure vessels and tanks were, in fact, essential to the chemical, petroleum, petrochemical and nuclear industries. It's during this category of apparatus that the reactions, separations, and storage of raw materials occur. Usually speaking, controlled instrumentation is needed for a large varies firm plant for storage and producing functions. The dimensions and geometric variety of pressure vessels vary greatly from the massive cylindrical vessels used for more-pressure gas storage to the tiny size used as hydraulic units for the craft. Some were buried within the ground or deep within the ocean. However, most were positioned on the ground or supported in platforms. Pressure vessels were typically spherical or cylindrical, with rounded ends. The cylindrical vessels were usually most popular, since they offer easier producing issues and create higher use of the obtainable area. Boiler drums, heat exchangers, chemical reactors, and so on, were usually cylindrical. Spherical vessels have the advantage of requiring diluent walls for a given pressure and diameter than the equivalent cylinder. Therefore, they're used for big gas or liquid containers, gas-cooled nuclear reactors, containment buildings for a nuclear plant, and so on. Containment vessels for liquids at terribly low pressures were typically within the variety of compound spheroids or within the form of a drop. This has the advantage of providing the simplest potential stress distribution once the tank is full [11].

Pressure vessels utilized in the firm were leak-tight pressure containers, typically cylindrical or spherical in form, with completely different head configurations that have been typically made up of carbon. Joining mechanism is used for assembly of the sheets. Early operation of pressure vessels and boilers resulted in various explosions, inflicting loss of life and extensive property injury. Some eighty years past, the American Society of Mechanical Engineers shaped a committee for the aim of building minimum safety rules of construction for boilers. In 1925, the committee issued a collection of rules for the configure and construction of unfired pressure vessels. Most states have laws mandating that these Code rules be met. Social control of those rules is accomplished via a 3rd party utilized by the state or the insurance firm. These Codes reside documents in this they're perpetually being revised and updated by committees composed of people knowledgeable on the topic, keeping current needs that the revised Codes be printed every 3 years with addenda issued once a year.

The Code configures criteria contains basic rules specifying configure methodology;configure load, allowable stress, acceptable material, and fabrication-inspection certification needs for vessel construction. {The configure |the planning the look} methodology referred to as "design by the rule" uses design pressure, allowable stress, and a configure formula compatible with the geometry of the portion to calculate the minimum needed thickness of the portion. This procedure minimizes the quantity of study needed to confirm that the vessel won't rupture or endure excessive distortion. In conjunction with specifying the vessel thickness, the Code contains several construction details that have got to be followed. Wherever vessels were subjected to advance loadings like cyclic, thermal, or localized masses, and wherever important discontinuities exist, the Code needs a lot of rigorous analysis to be performed. This technique is thought because of the "design by analysis" technique. Additional complete background of each strategy is found in Bernstein, 1988.

The ASME Code [1994] is enclosed as a regular by the American National Standards Institute (ANSI). The American petroleum Institute (API) has conjointly developed codes for minimum pressure storage tanks, and these are a part of the ANSI standards. The ASME Boiler and Pressure Vessel Code have been used worldwide. However, several different industrial countries have additionally developed boiler and pressure vessel codes. Variations in these codes typically cause an issue in international trade.

The forces that influence pressure vessel to configure depends on internal/external pressure dead masses because of the load of the vessel and contents; external masses from piping and attachments, wind, and earthquakes; operating-type masses like vibration and sloshing of the contents; and start up and closedown masses. The Code considers configure pressure, configure temperature, and, to some extent, the influence of different masses that impact the circumferential (or hoop) and longitudinal stresses in shells. It's left to the designer to account for the impact of the remaining masses on the vessel. Numerous national and native building codes should be consulted for handling wind and earthquake loadings.

Pressure vessels are the containers for the substances at excessive pressure. The pressure may additionally be acquired from an exterior source, or via the application of temperature from direct or oblique supply [2]. Pressure vessel subjected to inside pressure higher than the ambient is to be designed separately. There are separate design formulae for vessels subjected to internal and external pressure. The pressure vessel contains three parts namely dish, shell and skirt. Pressure vessels generally are rigid in nature and have a strong foundation. The connection between the pressure vessel and other equipment are made through pipes and in operating condition there exists a high pressure and temperature inside the equipment. This high pressure and temperature of the equipment will induce stresses, and there will be movement of the equipments.

In the existing plant, a fluid is pumped from system A of unit1 to system B of unit 2, where the fluid meets the process requirement and then it is moved back to system A of unit1. System A consists of pumps which pump the fluid and system B consists of two pressure vessels where the fluid is processed to meet the required property. It is proposed that new pressure vessels will be installed within the unit 1 to improve the efficiency of the plant. The pressure vessel is subjected to different sustain and operating condition. The design of the pressure vessel has to be carried out to satisfy the different temperature and pressure condition, to which it is subjected. Henceforth, it is carried out according to ASME section VIII division I [3]. This division carries obligatory requirements, particular prohibitions, and obligatory instruction for the force applied vessel material, design, fabrication, examination, inspection, testing, and certification and applied pressure remedy [1].

Typical vessel shapes used in the process industry are cylindrical and spherical. Spherical shells are self –closing while two ends of cylindrical shell need to be closed using closures of appropriate shapes. Depending on shell dimensions and service conditions the closure may be hemispherical, ellipsoidal, torrispherical, conical or flat.

Equipment is arranged in the plant, according to the flow sequence given in the Process Flow Diagram is called equipment layout. A pressure vessel is laid to satisfy the conditions as per OISD. Further, pipes will be laid to connect different types of equipment considering process flow, accessibility to valves, instruments, equipment maintenance, cleaning, optional safety, headroom clearance. A possible routing of the piping was done after completing of the piping layout.

2. DESIGN OF PRESSURE VESSEL

Design data

Design pressure – 14.5kg/cm2

Design temp- 250deg C

Corrosion allowance-3mm

Diameter -2800mm

Length-13630mm

Material- SA516Gr70

Joint efficiency factor E as per UW12=1

2.1 Design of Top Dish (Ellipsoidal Head 2:1)

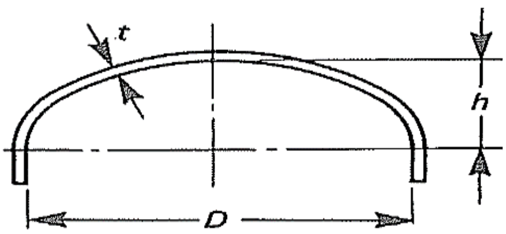

Figure 1: Ellipsoidal Head

2.1.1 Required Thickness due to Internal Pressure

t_r=PDK/(2SE-0.2P) Appendix 1-4© [1]

D/2h=2:1, a ratio of major to the minor radius

K = factor depending on the head proportion D/2h taken from table as shown in figure 2.

VALUES OF FACTOR *K*
(Use Nearest Value of *D*/2*h*; Interpolation Unnecessary)

D/2*h*	3.0	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0
K	1.83	1.73	1.64	1.55	1.46	1.37	1.29	1.21	1.14	1.07	1.00
D/2*h*	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0	...
K	0.93	0.87	0.81	0.76	0.71	0.66	0.61	0.57	0.53	0.50	...

Figure 2: Values of K

$t_r = \frac{(14.5\times2806\times1)}{2\times1407\times1-0.2\times14.5}$=17.47 =18mm

18mm plate is selected.

2.1.2 Max Allowable Working Pressure (t=15) at a Given Thickness

$P = \frac{2SEt}{D+0.2t}$ appendix1-4(a)

$P = \frac{2\times1407\times1\times15}{2806+0.2\times15}$=15.02kg/cm^2

2.1.3 Max Allowable Working Pressure at Cold and New Condition (t=18)

$P = \frac{2SEt}{D+0.2t}$appendix1-4(a)

$P = \frac{2\times1407\times1\times18}{2806+0.2\times18}$=18.02kg/cm^2

2.2 Shell Design

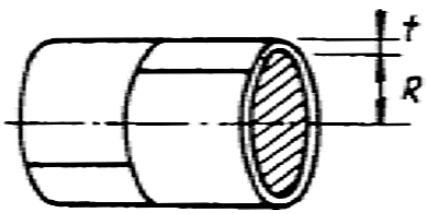

Figure 2.3: Shell

2.2.1 Thickness due to Internal Pressure

$t_r = \frac{16\times2806\times0.9}{2\times1407\times1+0.2\times16}$ as per UG-27© (1) [1]

t_r = min thickness required

R=inside radius of the shell=1400mm

S=Max allowable stress of the material=1407kg/cm^2 (137.886 N/mm^2)

E=joint efficiency factor from UW-12

P=design pressure=14.5kg/cm^2

$tr = \frac{14.5\times1403}{1407\times1-0.6\times14.5}$r =14.54+3 = 17.54 = 18mm

2.2.2 Max Allowable Working Pressure(t=15)

$P = \frac{SEt}{R+0.6t}$ as per UG-27(c)(1)

$P = \frac{1407\times1\times15}{1403+0.6\times15}$= 14.94kg/cm^2

2.2.3 Max Allowable Working Pressure at Cold and New Condition (t=18)

$P = \frac{SEt}{R+0.6t}$as per UG-27(c)(1)

$P = \frac{1407\times1\times18}{1403+0.6\times18}$=17.91kg/cm^2

2.3 Design of Bottom Dish: (ellipsoidal head 2:1) [1]

Pressure due to head= 1.5kg/cm^2

So the total internal pressure

$P = 14.5 + 1.5 = 16\ kg/cm2\ (1.569\ N/mm2)$

2.3.1 Required Thickness due to Internal Pressure

$\mathrm{tr} = \frac{\mathrm{PDK}}{\mathrm{2SE-0.2P}}$ Appendix 1-4©

D/2h=2:1, a ratio of major to the minor radius

K=factor depending on the head proportion D/2h taken from table 1-1.4

$\mathrm{t_r} = \frac{16\times2806\times1}{2\times1407\times1-0.2\times16}$=15.97+3=18.97mm

22mm plate is selected.

2.3.2 Max Allowable Working Pressure at a Given Thickness (t=19)

$\mathrm{P} = \frac{\mathrm{2SEt}}{\mathrm{D+0.2t}}$

$\mathrm{P} = \frac{2\times1407\times1\times19}{2806-0.2\times19}$=19.02 kg/cm2 (1.863 N/mm2)

2.3.3 Max Allowable Working Pressure at Cold and New Condition (t=22)

$\mathrm{P} = \frac{\mathrm{2SEt}}{\mathrm{D+0.2t}}$

$\mathrm{P} = \frac{2\times1407\times1\times22}{2806-0.2\times22}$=22.02 kg/cm2 (2.15 N/mm2)

3. RESULTS AND DISCUSSIONS

The design calculations were performed with respect to ASME section VII division I. The design condition and the material of the pressure vessel were stated by the client or by the process engineer. The plate thickness is calculated for different parts of the pressure vessel. The maximum thickness obtained is 18.97mm for the bottom dish, so 22mm thickness plate is selected based on availability at the market which holds good for all the parts of the vessel. The plate of thickness 22mm can withstand a pressure of 22 kg/cm^2.

The design calculations were carried out for different parts of the pressure, and suitable plate thickness was selected to manufacture the pressure vessel. The calculations, which were carried out according to ASME section VII division I was found are satisfactory for design pressure, temperature and material selected. The prime purpose of the pressure vessel is the storage of fluid at high pressure, and is the first step towards the design. It is true that all the pressure vessel components are selected on the basis of available ASME standards and the manufactures also follow the same during the fabrication. This reduces the work of the designer from designing the components. Due to this aspect of design, the time required for the development of a new pressure vessel is reduced greatly. Before finalizing the decision, the designer, and the freedom to try with multiple prototypes for the pressure vessel, which is another advantage of using ASME standards.

In the unit, pipes are connected to the pressure vessels for carrying the fluid to and from the vessel. The vessel and pipes will be subjected to different temperature as well as pressure during the operation. Since both are made of metal, they will expand during operating conditions, and they are subjected to stresses and strains. The pipes in the plant are considered to be a flexible member, and during expansion, they might put a load on the pressure vessel nozzle, which acts as a connecting point between pipe and pressure vessel. This will damage the pressure vessel, if the load exceeds the bearable limit. Hence, the piping design has to be performed. Process piping code B31.3 can be used to carry out the pipe thickness and design calculation [8]. Further, stress analysis of the pressure vessel and the connected pipe system may be performed to understand the flexibility of the pipes. Stress analysis of the piping can be performed using CAESAR [5] to keep the nozzle loads within the limit. Fatigue analysis of the entire structure maybe carried to check the fatigue life cycle of the pressure vessel [3].

REFERENCES

1. *ASME Section VIII Division I*
2. *B. S. Thakkar1, S. A. Thakkar2, "Design of Pressure Vessel Using ASME Code, Section VIII, Division 1", International Journal of Advanced Engineering Research and Studies, IJAERS/Vol. I/Issue II/January-March, 2012/228-234.*
3. *Niranjana. S. J et al., "Design and Analysis of Vertical Pressure Vessel using ASME Code and FEA Technique" Materials Science and Engineering **376** (2018)*
4. *Oil Industry Safety Directorate 118,2004*
5. *Prachi N. Tambe, K. K. Dhande, N. I. Jamadar "Flexibility and Stress Analysis of Piping System using CAESAR II-Case Study" ", International Journal of Engineering Research and Technology, IJERT/Vol.3/ Issue 6/ June 2014/370-374.*
6. *T V V Satyanarayana, V Sreenivasulu, Dr C Udaya Kiran, "Modeling and Stress Analysis of Flare Piping", International Journal of Latest Trends and Technology, (IJLTET), vol. 2, issue 1, pp. 219-225*
7. *"ASME Section II, Div. 1" 2007 Edition*

8. *"ASME B 31.3" 2008 Edition-American Society of Mechanical Engineers Process piping code*
9. *Gaurav Bhende and Girish Tembhare, 2013,"Stress Intensification and Flexibility in Pipe Stress Analysis" -International Journal of Modern Engineering Research, (IJMER) Vol-3, Issue-3, pp. 1324-1329*
10. *Rajesh, S., Kulkarni, B. M., & Shanmukhappa, S. (2014). Investigations on fuel properties of ternary mixture of ethanol, bio diesel from acid oil and petroleum diesel to evaluate alternate fuel for diesel engine. International Journal of Research in Engineering and Technology, 2(6), 181-188.*
11. *Nithin Kumar, HC Chittappa, S EzhilVannan "Development of aluminium-nickel coated short carbon fiber metal matrix composites" Mater. Today 5 (5), 11336-11345*
12. *Somanath Chattopadhyay "Pressure Vessel Design and Practice" CRC Press Taylor & Francis Group*
13. *HongjunLi, XunHuang, PengYang, HuiYang "A new pressure vessel design by analysis method avoiding stress categorization" International Journal of Pressure Vessels and Piping, Volume 152, May 2017, Pages 38-45*
14. *R. C. Carbonari et al. "Design of pressure vessels using shape optimization: An integrated approach" International Journal of Pressure Vessels and PipingVolume 88, Issues 5–7, May–July 2011, Pages 198-212*
15. *UjwalTejaMallampalli et al. "Design and Analysis of an Unfired Pressure Vessel for Conducting Pressure Test" IJIRST – International Journal for Innovative Research in Science & Technology| Volume 4 | Issue 3 | August 2017*
16. *Umesh, K. S., Pravin, V. K., & Rajagopal, K. (2014). Experimental Investigation and CFD Analysis of Multi-Cylinder Four Stroke SI Engine Exhaust Manifold for Optimal Geometry to Reduce Back Pressure and to Improve Fuel Efficiency. International Journal of Automobile Engineering Research and Development, 4, 13-20.*
17. *Imran M. Jamadar, Prof. R. M. Tayade, Mr. Vinay Patil 2012 "Structural Analysis of Inclined Pressure vessel Using FEM" International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 3, May – 2012 PP. 1-5.*
18. *Unfired Pressure Vessel Static and Thermal Testing code exclusive for IRDR.*
19. *Rohit Upadhyay Rahul Barjibhe Prashant Bajaj Vinay Patil, 2013 "Determining Stability of Overhang Pressure Vessel using Finite Element Analysis" International Journal of Engg. Research &Indu. Appls. (IJERIA). ISSN 0974-1518, Vol.6, No. IV (November 2013), pp 143-148*
20. *Mali, H. Bhosale, D. S. Bedi, A. Modasara, A review paper on the study of pressure vessel, design and analysis, Int. Res. J. Eng. Technol. 4 (2017) 1369–1374.*
21. *G. Ghanbari, M. A. Liaghat, A. Sadeghian, A. Mahootchi, Pressure Vessel Design Guides & Procedures, Navid Shiraz Publication, 2011.*
22. *C. P. Fowler, A. C. Orifici, C. H. Wang, A review of toroidal composite pressure vessel optimisation and damage tolerant design for high pressure gaseous fuel storage, Int. J. Hydrog. Energy 41 (2016) 22067–22089.*
23. *M. Maleki, G. H. Farrahi, B. H. Jahromi, E. Hosseinian, Residual stress analysis of auto frettaged thick-walled spherical pressure vessel, Int. J. Press. Vessels Pip. 87 (2010) 396–401.*
24. *Sawant, S. M., & Hujare, D. P. (2013). Thermo-mechanical analysis for skirt of pressure vessel using FEA approach. International Journal Of Mechanical Engineering (IJME) ISSN, 2319-2240.*
25. *M. Perl, M. Steiner, J. Perry, 3-D stress intensity factors due to autofrettage for an inner radial lunular or crescentic crack in a spherical pressure vessel, Eng. Fract. Mech. 131 (2014) 282–295.*

26. *M. Perl, M. Steiner, The beneficial effect of full or partial autofrettage on the combined 3D stress intensity factors for inner coplanar crack arrays and ring cracks in a spherical pressure vessel, Eng. Fract. Mech. 191 (2018) 426–440.*

27. *Ibrahim, Y. Ryu, M. Saidpour, Stress analysis of thin-walled pressure vessels, Mod. Mech. Eng. 5 (2015) 1–9.*